

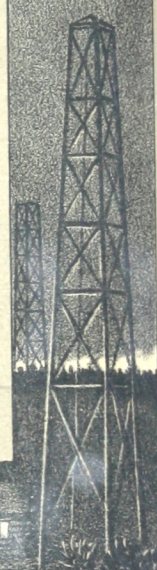
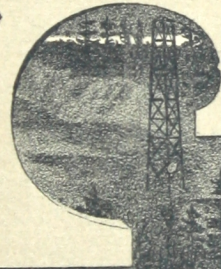
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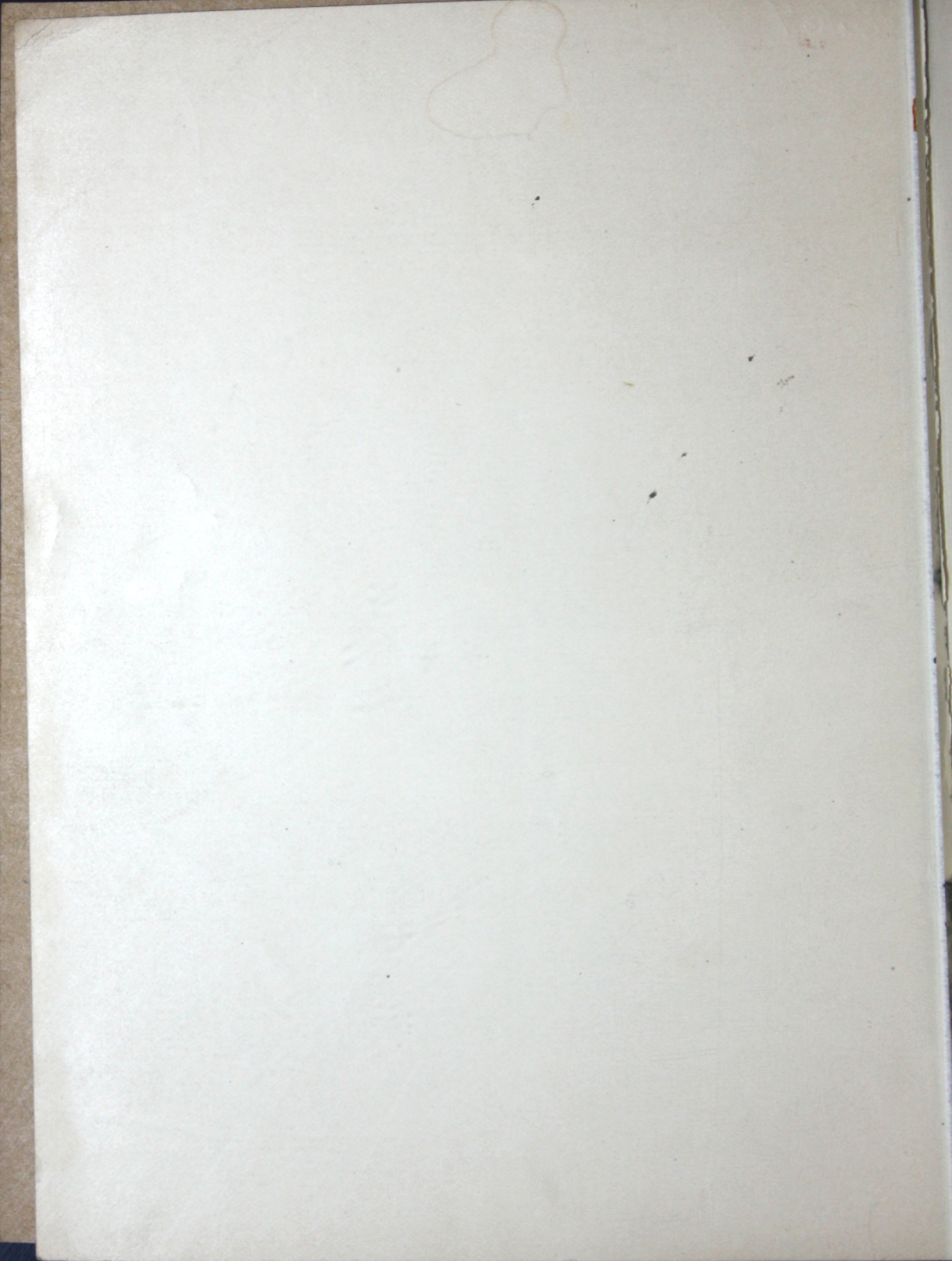
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Something about NATURAL GAS.



BALDWIN & GLEASON, N.Y.

Published by L. BANNISTER, 64 Park Place, N.Y.





SOMETHING ABOUT
+ NATURAL GAS +

ITS ORIGIN, EXTENT AND
DEVELOPMENT.

The Piping Systems, Safety Appliances and Devices
for its Safe and Economic Utilization.

Gas the Fuel of the Future.

BY

LEMUEL BANNISTER.

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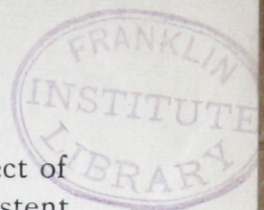
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PREFACE.



I have been led to prepare this review of the subject of Natural Gas and its utilization, by the frequent and persistent inquiries that have come to me for such information. In doing this I have been guided by an experience of several years, during which time I have had personal contact with every phase of the subject, and close personal and business relations with nearly every one connected with natural gas enterprises in every part of the country where its utilization has been attempted.

If what I have written shall supply, even in part, the want that seems so generally to be felt, my chief object will then have been accomplished.

Any one who stops to consider the great economic importance of this gas and its influence upon the industrial prosperity, and the health, comfort and happiness of the people in the localities where it has been utilized, and also its direct and irresistible demonstration of the fact that gas of some kind is to be the fuel of the future, cannot but be impressed that the current literature of the subject is very meagre.

I have aimed to present a fair exposition of the origin, extent and development of this gas, as gathered from the investigations of the leading geologists and other men of science, and to give, as well, a careful description from personal knowledge of the pipe systems and mechanical devices employed in its conveyance and utilization.

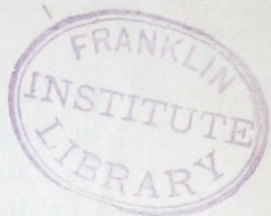
If, in doing this, I have incidentally digressed to criticise the means employed by illuminating gas companies and to read them a short lecture on their misdoings, it is explained by the fact that they deserve it, and that the occasion fully requires and justifies what I have said.

60 Park Place,
NEW YORK, October 1st, 1886.

L. B.

"Fuel is to the steam engine what the main-spring is to a watch—the source of its power and the measure of its effects. Indeed, fuel may be regarded as the main-spring of modern civilization, for there is scarcely a process in the mechanical arts in which heat obtained from its combustion is not a prime agent.

"Fuel as a prime agent,—as one of the mightiest of visible motors which a bountiful Providence has placed at our disposal, is too precious a gift to be carelessly squandered, in view of the constantly increasing requirements of civilization."



INTRODUCTION.

Among the most important developments of the present century, natural gas is clearly entitled to a conspicuous place. Its utilization for fuel and the phenomenal success which has attended its general introduction and use in Pittsburgh and vicinity, in the manufacture of iron, steel and glass, and for domestic and other purposes, marks a new era in the progress of events, and presents to similar industries in other localities a very serious question in the economy of production. It has so cheapened and improved in quality these products of manufacture, that, with coal for fuel, successful competition is entirely out of the question.

Pittsburgh, with the advantages thus secured, holds a commanding position with respect to the production of iron, steel and glass, which has already brought to her a wonderful prosperity. The difference of cost, in her favor, is so great, that in most instances the products of steel and glass-works can be delivered in other competing centres, at a fair profit, and yet for less than they would there cost to produce.

Pittsburgh, therefore, so long as this state of affairs exists, may dictate as to whether similar industries in other localities using coal for fuel, shall enjoy a fair meed of prosperity or not.

It is a matter of earnest congratulation, however, to such localities, that geologists so fully agree upon the theory that natural gas may be found in rocks of any geological age, and that gas horizons, therefore, may exist in formations that extend over vast areas. There is certainly in this a reasonable hope that localities at present placed at such disadvantage, may, by proper exploration, find natural gas within practicable

pipings distance. This can only be actually determined by drilling wells, and it is plain that such localities should not hesitate to apply this test with as little delay as possible.

But if they should fail in this, there is still another and very efficient means of securing an economic fuel which can be readily made available. The lesson so thoroughly impressed by natural gas leaves no doubt that gas for fuel is almost immeasurably superior to coal. The feasibility of successfully manufacturing a fuel gas is already an established fact, and its advantages are so great, as compared with coal, that surely its manufacture should proceed at once in every locality where natural gas cannot be found in abundance.

In the present advanced state of physical and chemical science it is certainly possible to produce a fuel gas which, in point of cost and quality, will place these competing centres on at least as good a footing with respect to Pittsburgh, as that which they occupied for so many years under the coal *régime*, and this in the main should be satisfactory to them.

Natural Gas, its Origin and Development.

Within the past few years Natural Gas has become a subject of profound public interest in this country. For many generations it has been known to exist in vast areas, at widely separated points, and it has been utilized in a few instances for lighting and warming houses, and, in a small way, for manufacturing purposes, but until quite recently its great economic value, as a fuel, was little dreamed of.

Existence of
Natural Gas
long known.

In the abundance of other resources this valuable product seems to have been left to take the ordinary course of things, until, partly by accident, its great importance was forced upon the attention of manufacturers and users of fuel in general. It was soon demonstrated by practical experiments in Pittsburgh, that, in the manufacture of iron, steel and glass, and for general use, this fuel was so superior in all respects that its universal adoption would depend simply upon the question of obtaining a supply of it.

Even with crude and unscientific appliances, and with little knowledge of the proper use and control of the gas, it was found that the quality of these articles of manufacture had been greatly improved by its use, and the cost of production much reduced; it was found, too, that in generating steam an even pressure could be easily maintained without injury to the boiler, and in warming houses any required temperature could be kept up. In short one advantage succeeded another, and in every new use others were added to the list until the above conclusion was inevitable.

Its great economic value
only recently
discovered.

Fortunately for Pittsburgh and other manufacturing centres in that locality, a supply of it was near at hand, and

there has been no lack of energy or enterprise to make it available for all purposes; nor has there been any lack of special and scientific investigation to develop its possibilities and to devise proper means for its conveyance and distribution, and suitable appliances for its control and economic use. As though by mutual agreement all set to work upon the main problem, each in his appropriate field, and the outcome is gratifying to contemplate. We shall revert to this later on.

Probable Extent and Permanency of the Supply.

Speculation
as to supply.

Naturally the first question that presented itself for both practical and scientific investigation was the probable extent and durability of the supply. This led up to several collateral questions as to the origin of this gas, its relations to oil and coal, and whether, indeed, the Great Maker of the Universe who has so bountifully provided us with this extraordinary fuel has not also provided for its continuous production in Nature's laboratory to supply future ages.

The Driller's
opinion.

The investigation took a wide range and enlisted the careful thought and attention of eminent geologists and chemists and other specialists. The practical driller, as usual, had his opinion, and he still has it, namely: that there is an abundance of gas for all purposes, and for all time to come, if it can only be found. On general principles it is the belief of some that gas exists in abundance to supply all wants, and their explanation is, simply, that Nature never does anything by halves.

The geologists and other scientists, however, to whom we must look for light—since the driller's hope or the simple belief in Nature's liberality, cannot be followed as a safe guide.—have devoted themselves with consummate energy and ability to the consideration of both the practical and the theoretical aspects of the problem. While their conclusions may differ, as they do, upon some phases of the subject, it is nevertheless a matter of congratulation that the majority of them are able to agree upon most of what are presumed to be the primary facts relating to the geology of natural gas, and an examination of their reasonings cannot but prove interesting and profitable.

The Geologists carefully investigate the subject.

Prof. CHAS. A. ASHBURNER, Geologist in Charge, Geological Survey of Pennsylvania, (Report 1885, pp. 3, 6), refers to the subject as follows :

"The general conditions upon which the occurrence of natural gas seems to depend, from a consideration of the facts at present at our command, are : (a) the porosity and homogeneousness of the sandstone which serves as a reservoir to hold the gas ; (b) the extent to which the strata above or below the gas-sand are cracked ; (c) the dip of the gas-sand and the position of the anticlines and synclines ; (d) the relative proportion of water, oil and gas contained in the gas-sand ; and (e) the pressure under which the gas exists before being tapped by wells."

The primary conditions of the existence of Natural Gas

Again, he says :

"The origin of natural gas has an important bearing upon its economic geology. Although it is believed that we are in possession of much data to throw some light upon this interesting question of cause, yet it is still shrouded in too much uncertainty to permit of complete explanation. It is necessary, however, that some statement should be made in regard to the origin of gas in order to thoroughly comprehend the conditions upon which its existence seems to depend."

Origin due to decomposition of animal and vegetable life

"It would appear that the gas is closely related to petroleum, and that their origin is due largely to the same cause—the decomposition of animal and vegetable life."

"It is believed that the gas is not indigenous to the sand-rock, from which it is obtained, but comes from the decomposition of life-forms which were entrapped in underlying strata. If this be so, the amount of gas contained in any one sand depends, first, upon the extent to which the rocks are cracked between the horizons of such organic remains and the gas-sand reservoir, in order to permit the gas to flow into the sand; and second, upon the extent to which the rocks are cracked above the gas-sand, which would permit the gas to escape into the atmosphere and totally disappear."

Prof. EDWARD ORTON, (Report 1886, p. 6), State Geologist of Ohio, presents the following view:

Oil and Gas
have a com-
mon origin.

"It is not necessary to consider the origin of natural gas and petroleum separately. They have a common history. They are produced from the same sources, accumulated by similar agencies, and stored in the same reservoirs. In order of formation, petroleum is probably first. It is the more complex in composition, and thus nearer to the organic world, from which it is derived. Gas is the same substance on the downward road to the simplicity of inorganic compounds. No process is known by which gas is built up into oil; but the breaking up of petroleum into gaseous products is seen to be constantly going forward in nature, and it is also effected in the large way artificially."

"Petroleum never exists free from gas, but it is sometimes asserted that gas is found that has no connection with petroleum. This claim is probably a mistaken one. * * * There is no horizon known that produces either substance to the entire exclusion of the other."

"As already implied, petroleum and gas are derived from the organic world. Both vegetable and animal substances have contributed to the supplies, and these separate sources give different characters to their products, as will be presently shown. There are certain other theories in regard to the origin of petroleum, it is true, which have been advanced by eminent chemists, but which do not match at all well with the geological facts involved."

"These last named refer petroleum to peculiar decompositions and recompositions, chiefly of water and carbonic acid, which are supposed to be carried on at considerable depths in the earth where these substances are brought into contact with metallic iron, or with the metallic bases of the alkalies at high temperatures."

"Never were more artificial or unverifiable theories presented for the explanation of natural phenomena, and it is surprising that they should have obtained any currency whatever. Something might be said for them, perhaps, if we had no other possible way of accounting for the facts to which they refer; but when they are compared with the theories of organic origin they have no standing ground."

Argument
against the
chemical
theory.

"The truth is, we are constantly manufacturing from animal and vegetable substances, in the large way, both gas and oil that are fairly comparable, in both chemical and physical characteristics, with the natural products. Further, we find vegetable substances passing by natural processes into petroleum and allied compounds, so that there is no need whatever to invent a strained and fantastic theory based on remote chemical possibilities, in order to cover the ground."

"These chemical theories teach that the process of oil and gas formation is a continuous one. * * * Perhaps it is this feature that has recommended these theories more than any other. Any doctrine that gives us unwasting supplies of force is sure to be popular as long as it can find the semblance of justification, as witness the hold that the claims for perpetual motion have on the public mind."

"The petroleum and gas of shales and sand-stones are in the main derived from vegetable matter, and as the principal stocks are found in sand-stones, vegetable matter may be said to be the chief source. The oil and gas of limestones are presumably derived from animal matter, inasmuch as the limestones themselves are known to be, in the main, a product of animal life."

The gas a pro-
duct of ani-
mal and vege-
table life.

Prof. McMILLAN, President Ohio Institute of Mining Engineers (Mining Journal, pp. 14, 15), says of the origin of natural gas:

"It is generally conceded that natural gas, as well as petroleum, is generated from the carbonaceous material of the deeply buried shales,

There are many, however, whose opinions are worthy of consideration, who believe that the oil-sands are the real producers, and still others who believe that the oil and gas come from the limestone. I think incontestable proof can be offered that all are right."

Newberry's
theory.

"In a paper read in February, 1882, Dr. NEWBERRY says that the oils of the Niagara limestone are indigenous in that rock, and believes they are of animal origin. In this same paper he says the gases of the Hamilton shales are from the carbonaceous matter, apparently produced from the decomposition of sea-weed, these being abundant and nearly all other fossils absent."

"Very many eminent authorities may be quoted in maintenance of the claim that the natural oils and gases of some horizons at least are of animal origin."

Peckham's
opinion.

"Prof. PECKHAM says Ohio and Pennsylvania oils are undoubtedly of vegetable origin, but thinks the Kentucky oils from the Trenton limestone are from animal origin. This statement was made, however, before the development of the new gas and oil-fields of Northwestern Ohio."

Hunt's views

"Prof. T. STERRY HUNT attributes the origin to animal matter. There are others that reason that it is possible that they are neither of animal or vegetable, but that the origin is purely chemical—that is, the result of chemical action upon inorganic matter."

Byasson's ex-
periment.

"BYASSON, of France, by experiment in 1871, produced petroleum from water and carbonic acid in contact with white-hot iron. A possible theory is suggested that sea-water invades greatly heated portions of the earth and comes into contact with unoxidized, highly heated metals. BERTHELOT, in 1866, suggested nearly the same theory, viz.: the formation of acetylene by contact of carbonic acid with alkaline metals in the bowels of the earth, and then through action of steam, carbides of hydrogen are formed.

The Chemi-
cal theory.

"M. MENDELIEFF, of Russia, in 1877, suggested that the law of gravity must put metals nearest the centre of the earth. Water has reached the metallic carbides through crevices, and carburetted hydrogen is formed.

"It seems evident to me that gases are found in rocks to which they are indigenous, and in rocks where they have only been stored; that they are of animal, vegetable and chemical origin."



In attributing the origin of natural gas to chemical action as one of the causes of its occurrence, Prof. McMILLAN expresses the theory which is distinctively announced by the chemists and which may possibly prove to be correct. But it is the opinion, on the other hand, of all the professional geologists who have examined the Pennsylvania and New York oil and gas-fields, that the chemical theory accounting for the existence of oil or gas is quite insufficient; in fact that the evidence gathered in these fields throws reasonable doubts upon the correctness of the chemical theory as applied to any oil or gas-field.

Theory on which Geologists unite.

Prof. LESLEY, State Geologist of Pennsylvania, in speaking of the durability of our natural gas supply, says:

Lesley's views—Gas supply is exhaustible.

"I take this opportunity to express my opinion in the strongest terms that the amazing exhibition of oil and gas which has characterized the last twenty years, and will probably characterize the next ten or twenty years, is, nevertheless, not only geologically but historically a temporary and vanishing phenomenon—one which young men will live to see come to its natural end.

"And this opinion I do not entertain in any loose or unreasonable form. It is the result of both an active and a thoughtful acquaintance with the subject. * * * For I am no geologist if it be true that the manufacture of oil in the laboratory of nature is still going on at the hundredth, or the thousandth part of the rate of its exhaustion. And the science of geology may as well be abandoned as a guide, if events prove that such a production of oil in Western Pennsylvania as our statistics exhibit can continue for successive generations. It cannot be; there is a limited amount. Our children will surely, and with difficulty, drain the dregs.

"I hold the same opinion respecting gas, and for the same reasons, with the difference merely that the end will certainly come sooner, and be all the more hastened by the multiplication of the gas wells, and of the fire-boxes and furnaces to which it is led."

And he adds the following opinion :

Lesley's
conclusion.

"As gas is a direct product of petroleum by spontaneous evaporation, the life of the gas production will be limited by the amount of the volatile elements held in a definitely limited quantity of petroleum existing under ground ; and, therefore, those who are producing and using this enormously valuable mineral substance, should take every precaution to prevent its waste, seeing that it is bound to come to an end."

Mr. JOHN F. CARLL (Prelim. Report, 1886, pp. 30, 34), the able assistant to Prof. LESLEY, and who has had a long experience in the oil and gas-fields of Pennsylvania, in referring to the relations of gas and oil, says :

Gas and Oil
intimately re-
lated.

"Gas and oil are so intimately related that an oil-field must necessarily be a gas-field. From one end of the oil belt to the other, gas has been found in larger or smaller quantities in every oil well drilled. But the conditions under which it exists are quite variable. Sometimes large flows issue from sand-stones lying above the oil-producing rocks, sometimes from the oil-sand and with the oil, and in other cases it may be from sands below the oil horizons. 'Gas Streaks,' as they are popularly called, are areas where the rock contains more gas than oil, are common throughout the oil-regions, skirting the edges of good territory in some places, or streaking the central portions of it in others.

"It does not follow, however, that every gas well must produce oil, for even within defined oil-fields there have been gas wells that made no oil beyond a slight condensation in the delivery pipes ; and elsewhere gas-producing rocks are sometimes absolutely barren of oil in the gas horizons."

In the same report (p. 46) in discussing the anticline theory, he gives the following interesting account of the geological formation :

Origin of gas-
sands.

"It is well known that all our oil rocks are sedimentary ; that they are composed of materials derived from older rocks, the disintegrated particles of which have been sifted, assorted and deposited in stratified

layers by the action of water. These rocks are known to be several thousand feet in thickness, and untold ages elapsed while they were forming.

"For the purposes of this discussion we need go no further back in the eons of the past than the time when the Murrys-ville gas-sand (taking a definite stratum to avoid confusion) was completed by those changes of conditions (whatever they were) which terminated the sand deposits at that spot and commenced to lay down the overlying shales. At that date the two most important requisites for a future gas field had been provided. The gas-making material had been deposited; the necessary tank, so to speak, put in place, and the impervious cover was being put on. But the sedimentary deposits were not yet completed. Other carbonaceous shales, other sand rocks, alternating with beds of coal, slates, fire-clays and limestones, were yet to be superimposed to the height of 3,000 feet or more.

"These all were deposited in the course of time in regularly stratified layers, showing that no deep-seated, unequal or local disturbance had occurred up to the date of their completion. Subsequently some great change took place; the whole region was lifted above ocean level; the Allegheny Mountains rose in crested ridges, and the Murrys-ville anticlinal, with other comparatively minor flexures, was formed.

* * *

"The drill has demonstrated that the permeable sand-rocks lie in beds so inclosed in impervious shales that each bed practically forms a reservoir by itself. In certain horizons these sand-beds are numerous and persistent. But each individual bed has its *locus* and its characteristic fluids. In the same well one may produce water, another oil, another gas, another a mixture of all three, and only a few feet of shale intervene between the different layers of sand stone. All these rocks were equally effected by the general uplift, and now lie dipping to the southwest at an average rate of from 18 to 22 feet per mile."

Varying characteristics of gas-sands.

Further on in the same report (p. 51), Mr. CARLL refers to the question of inexhaustibility of natural gas, as follows :

"The inexhaustibility of natural gas wells is another popular fallacy which has gained some standing since drilling for gas commenced near Pittsburgh. * * *

Carll's theory
Inexhaustibility a popular fallacy.

A permanent gas-field implies a number of neces-

sary conditions, and suggests many curious questions, among which are the following : Inexhaustible wells must draw from inexhaustible sources. Gas in Pennsylvania is only found in sand-beds of medium thickness and restricted geographical limits. Such beds in themselves cannot be inexhaustible. Their productive duration depends entirely upon the drafts made upon them—a simple problem—if one well can exhaust one of the beds in 100 years, how long will it take 100 wells to do it ? To make such pools permanent they must be constantly replenished from an unlimited source. This source, it is claimed, is some deep-seated laboratory of nature capable of responding to all demands that can be made upon it. * * * Perennial gas-springs abound in some sections of the country; but if the permanent flow from them is to be taken as the measure of the gas-generating forces, it is evident that it is altogether too insignificant to meet the demands of inexhaustible theorists.

A problem in
Arithmetic.

Gas deposits
near Pittsb'g
large and well
stored.

"The gas deposits around Pittsburgh are evidently large and well-stored, and capable, no doubt, of supplying a reasonable number of wells many years. But if too copiously drawn upon—as they are likely to be under the present contagious excitement—not alone for the purpose of supplying legitimate demands, but also through excessive drilling in all directions, by parties who have no gas mains, but lease and drill as a matter of speculation, wasting the gas if successful, until a satisfactory sale can be forced—they must soon become exhausted to such a degree that it will be found necessary to extend the gas mains to new pools (if they can be found) or to supply them with manufactured gas."

We have quoted liberally from the reports of these eminent geologists with the view of presenting, in convenient form, the different theories and opinions that are advanced touching the origin, extent, and durability of natural gas. The subject presents many interesting features and it must be obvious to all that it is still to a great extent shrouded in mystery. There are few, if any, more interesting phenomena in the economy of nature, and it may also be said that there are few, if any, geological problems more difficult of solution.

The researches of the leading American geologists strongly suggest the conclusion that it is quite possible for oil and gas to be found in greater or less quantities in rocks of almost any geological age; that in fact the existence of oil and gas in any locality is more dependent upon the geological conditions under which the stratified rocks are found to occur, than upon the geological age of the rocks themselves. We may deduce from this that the gas-bearing rocks of this country may extend under vast areas which hitherto have not been explored.

Gas may be found in rock of any geological age.

This conclusion is, in fact, entitled to the fullest credence, for it has already been demonstrated by the drill, that natural gas exists in the underlying strata, not only in various sections of Pennsylvania, where the supply is enormous, but in Eastern, Western and Middle New York, in the Province of Ontario, in many widely separated parts of West Virginia, Ohio, Indiana, Illinois, Wisconsin, Missouri, Kansas, Kentucky, and the Territory of Wyoming. The developments in some of these states, notably Ohio, Illinois, Kansas, West Virginia and Kentucky, indicate a very large supply of this gas.

Gas exists in vast areas.

The drill of the restless prospector is constantly widening the limits of its known occurrence, and, already in several localities, in these states, corporations have been formed to make the product available. It must be evident, therefore, to the most casual observer, that Pennsylvania is not likely to enjoy a practical monopoly of this perfect fuel for any great length of time.

Chemical theory of continuous supply may prove correct.

It is clearly possible that the theory as to the origin of this gas, which is the least supported now, namely, that it is due to chemical action and that the supply, therefore, will be contin-

uous, may prove correct. But it is also clear that the weight of authority now is on the side of exhaustion, or nearly so, of the natural gas supply before many years, if the present improvident waste of it is allowed to go on, or if the legitimate drain upon it continues to increase as it no doubt will.

If this latter theory should prove to be true there can be no doubt in the minds of those who have given the subject much thought, that, upon the partial exhaustion of natural gas, an artificial gas will take its place for all manufacturing and heating purposes.

Natural Gas has demonstrated the practical utility of Gas for fuel.

Nature has furnished the purest fuel known, and whether it lasts in abundance for only a few years, or for many generations, or all time to come, it has already taught us many lessons of great significance and secured to us many permanent blessings. It has thoroughly demonstrated the great practical utility of gas for fuel in the manufacture of iron, steel and glass, and for generating steam. It has promoted health, comfort and happiness, and made cleanliness possible in the household, by supplanting coal, and its smoke and dirt. That these and other benefits might be realized it commanded the best abilities of the inventor to devise suitable means for its conveyance, distribution and control, and it has thus been the direct cause of great improvements in pipe systems, and all the appliances for safety and economy in the use of gas of all kinds and for all purposes.

Great improvements in pipe systems.

Pressure sometimes 500 lbs. to the square inch a warning.

By its great pressure (sometimes reaching 500 pounds to the square inch), and its terrific explosive energy, early and too frequently demonstrated, natural gas warned the public that every precaution should be taken, (a) to prevent leaks ;

(*b*) to detect leaks; (*c*) to provide means for confining it within known limits, and for carrying off to places of safety any gas that might possibly escape through the joints of the mains; but first of all, that there be no structural or mechanical defects in the pipe system, and that the pressure be regulated so as to allow not more than a few pounds in street mains, and not more than a few ounces near the point of combustion.

Safety precautions necessary.

This warning, however, was not heeded until after, in several instances, gas had found its way from leaky joints or imperfect pipe systems to the cellars of houses and fearful explosions occurred, causing great destruction of property and the loss of several lives.

Dangers of imperfect pipe systems.

The subject then assumed a serious aspect, and it was here that the court of Allegheny County, Pennsylvania, took cognizance of the danger to life and property that was imminent, if careless methods and unsuitable means continued to be employed in the conveyance and distribution of natural gas; and a Commission consisting of five able experts was at once appointed, with power to subpoena witnesses and administer oaths, and with instructions to investigate the materials and mechanism of the pipe systems and collateral appliances then in vogue for conveying and delivering this gas.

Commissions to investigate dangers appointed by Court.

It was here, too, that the inventor, the capitalist, the scientist, the mechanical engineer and the skilled mechanic joined hands, as it were, and backed by public sentiment and the desire to make available this valuable product of nature, applied their best abilities and produced results of permanent importance to all gas enterprises, and to the public generally.

Order of Court appointing Commission.

ALLEGHANY COUNTY, SS. COURT OF COMMON PLEAS, No. ONE

Order of
Court
appointing
Commission.

THE CITY OF PITTSBURGH,

vs.

THE FUEL GAS COMPANY,
a Corporation,

AND

THE PENN. GAS COMPANY,
a Corporation.

*No. 530, March, 1885,
In Equity.*

"And now, February 25th, 1885, on motion of both parties to the above suit, E. Y. BRECK, Esq., is appointed Commissioner; and GEORGE BROWNE, JAMES T. BARR, JACOB SCHINNELLER and JAMES B. McFADDEN, Esqrs., coadjutors, to examine into the condition of defendants' pipe lines now in use, or intended to be used, by said Companies for the purpose of transporting natural gas within the City of Pittsburgh; the manner of their use, present or prospective (including the degree of pressure thereon), and the dangers of explosion or other public injury incident to, or likely to arise from, the use of said pipes by said defendants for transporting and supplying said gas to consumers.

"The said Commission is also directed to specially inquire into all points of danger along said lines of pipes, for the purpose of locating the same (if any shall be found to exist), and generally into all matters pertaining to the safety of citizens, so far as affected by the use of the same. They are also empowered to issue subpoenas for witnesses, and examine them under oath upon such matters, and directed to make report thereon to the court within sixty days herefrom, with such suggestions as they see proper to make in the premises in regard to what, if anything, may be necessary to be done by defendants to render the use of said pipe lines compatible with public safety. A special report to be made at any time in reference to any apparent or probable danger of explosion in any particular locality, should any such become manifest before final report.

"And now, February 26th, 1885, JAMES P. BARR, Esq., having declined to serve as Commissioner in the above case by reason of his necessary absence from the city for some time to come, JOHN B. LARKIN, Esq., is now appointed to serve in his place and stead.

"From the record.

BY THE COURT.

"J. O. BROWN, Prothonotary."

The inquiry of the Court Commission extended over a period of about three months, and it covered a wide scope. Professional experts in all the kindred arts, as well as practical engineers and mechanics, were called and closely questioned, and much valuable information was elicited. The art of pipe-making and pipe-laying, and the construction of the various joints and safety appliances, which were either proposed for use as being novel, or which seemed to have the sanction of experience; and also the chemical and physical characteristics of natural gas, came within the purview of this inquiry.

The Commission found, and so reported to the Court, that no line then owned or controlled by the defendants should be used as a high pressure line within the city limits, and it was their opinion that a pressure greater than ten pounds should not be allowed on low pressure lines.

Commission
found pipe
lines to be
defective.

In referring to some of the difficulties then commonly met with in controlling this gas, they say in their report to the Court (pp. 23, 24):

"Natural gas, commonly called marsh gas, owing to its low specific gravity (being but little over one-half the weight of air), and extreme tenuity, is exceedingly difficult to confine. If the lines used to convey it are not absolutely tight, the gas will escape and will seek the easiest outlet to the atmosphere.

"In summer, when the earth is open and porous, it readily rises to the surface of the ground, is dissipated through the atmosphere, and no harm follows. In winter, when the ground above the conduit is frozen, a

seal is formed which prevents the gas rising to the surface, and it escapes laterally through the unfrozen earth and follows drains and service pipes into cellars, sewers and other openings, and its presence is difficult to detect owing to its being comparatively odorless.

Special dangers of Natural Gas.

"As cellars are usually kept closed during cold weather, they are liable to become magazines of gas, readily fired when flame is brought in contact with it. The range of explosibility of natural gas, as shown by the experiments of Dr. HAY (see Appendix), is greater than that of coal gas, but the resulting explosion is less in violence, and it also requires a higher degree of heat to fire it. In other words, the conditions being equal, coal gas is the more dangerous."

Safety appliances required.

It was clear to them, as is well known now, that pipe systems and safety appliances for conveying and controlling natural gas should be of the most approved construction and laid in the most careful manner possible. And in referring to the most effective utilization of this valuable fuel, they say on (pp. 26 and 27) of their report :

Commission's views on gas combustion.

"The matter of the economical consumption of gas, is one that should receive attention from consumers, all natural gas companies and the insurance companies. When first introduced into the city there was but little knowledge on the subject of the proper method of using gas. Small pipes were laid through the mills, and high pressures were consequently necessary to supply them with sufficient gas.

"Of late, vast improvements have been made in the fitting up of mills and burning of the gas, and it is found that the best results are obtained by consuming it at low pressure, increasing the volume of the flow by increasing the size of the mains. A number of the largest manufactories in the city are now supplied at a pressure not exceeding a pound and a half, again reduced at the furnaces, and entering them at a pressure not exceeding two ounces, which is the ordinary pressure on artificial gas mains, with the best results.

"It will be seen by the analysis of Dr. GEORGE HAY (see Appendix), that natural gas is but little over one-half the weight of air (the specific gravity being .52, air 1), and to obtain perfect combustion requires a chemical combination of about ten volumes of air to one of gas. If the

gas enters a furnace at high pressure a proper chemical mixture with the atmosphere is not obtained, and as a result there is a waste of gas, and consequently an unnecessary drain on the supply pipes.

"We recommend that all Natural Gas Companies require their consumers to connect all supply pipes in such a manner as to form circuits, and insist that the gas be consumed at a pressure not exceeding two ounces."

A perfect pipe system and safety appliances required.

The work of the Commission was performed admirably, and its recommendations to the Court impressed the public mind that the greatest degree of caution should be insisted upon in laying pipe-systems to convey this gas, and that every safeguard should be provided to prevent its waste and the disasters which are almost sure to follow.

The Problem which Natural Gas presented.

While this investigation was in progress, and for some time previously, as well as thereafter, the ingenuity and skill of the inventor and of the mechanical engineer were devoted to the work of devising and perfecting a safe system of piping and suitable appliances for the control, distribution and economic consumption of this gas. This was a prime necessity, in order, first, to secure the great benefits that would doubtless result from the proper utilization of this valuable fuel; and second, to relieve the public mind of apprehension by affording reasonable protection to life and property against the dangers of explosions. To accomplish this the problem which presented itself was to provide reliable means of securing the gas at the wells under a pressure often developing five hundred pounds to the square inch, and of transporting it

A prime necessity.

tnence without leakage to the place of combustion, and there delivering it under a pressure not exceeding two ounces to the square inch.

Any one who has heard steam blow off in a locomotive under a pressure of one hundred pounds to the square inch can comprehend to some extent the great force of natural gas, and the difficulty of controlling it under a pressure of five hundred pounds. But this has been accomplished, and, as will presently appear, the problem in its entirety has been completely solved.

The Piping System.

The difficulty
of making
pipe joints
gas-tight.

After providing efficient valves and anchorage to shut in and control the gas at the wells, so as to prevent wastage there of this valuable fuel, attention was then given to the character of the pipes that would be the best adapted to transport it to market. It was found that wrought iron, by reason of its greater tensile strength, would be superior for high pressure lines to carry the gas through the open country to the city limits, but many advantages were conceded to cast iron for low pressure pipes within the city. It was found to be practically impossible to make absolutely tight screw-joints that would remain so in a long line of wrought iron pipes, but in the open country where these pipes would be laid the leakage was not liable to do harm.

For the delivery of gas under low pressure it was found that larger pipes than could be made of wrought iron in the present state of the art, would be required to deliver the quan-

tity that would be demanded, and as cast iron could be made of any size required and of proper strength, it was preferred for low pressure. It is also less liable than wrought iron to be impaired or broken in the line by any strain or movement caused by expansion or contraction; being in twelve-foot lengths, and the joints packed and caulked with lead, it readily compensates, and without material injury, for any strain or movement due to the variations of temperature that are likely to occur below the frost line.

Different
kinds of
pipes used.

But in cast iron lines, as in wrought iron, it was found practically impossible, in the ordinary way, to make absolutely tight joints that would in every case remain so. The settling of the earth and of the pipes in places, as often occurs in streets that have been graded by a "fill," or a slight change of the alignment, caused by the frost or any great variation of temperature, is liable to impair the packing of the joints, and then leaks occur, and the gas under pressure may escape in dangerous quantities.

Testing Pipes and Joints in the Trench.

With the exercise of the utmost care in making and caulking the joints of cast iron pipes with lead or cement it will sometimes occur that the work has been imperfectly done, or that some defect has escaped notice. And in respect to the screw-joints of wrought iron pipes the mechanical difficulty of making them perfect is well nigh insurmountable; if in cutting the threads the tap or die becomes dull or worn there may be a variation in the angles of the threads, or when screwed to-

Laying pipes
and testing
joints

gether a spiral opening may be left over their crown through which gas will escape ; and again they may be damaged by being improperly entered or crossed in screwing the pipes together. In any such case leakage is almost sure to occur.

The only
sure way.

The only sure way to detect these imperfections is to test by air or gas under pressure every section of say five hundred feet as it is laid in the trench to about fifty pounds to the square inch on mains intended for low pressure, and on high pressure mains to two or three times what they are expected to carry. No pipe system for gas, whether intended for natural gas, coal gas, or water gas, under either high or low pressure, should be allowed to be covered in the trench without first being subjected to this test, and the imperfections properly repaired.

Air preferable
to gas for test-
ing.

Air is preferable to gas for testing pipe lines, as it is altogether efficient, and unlike gas, it avoids the great danger of explosions and injury to the workmen when the test is finished and it is allowed to escape into the atmosphere.

Safety Appliances.

It being practically impossible, as stated, to make a series of joints in the ordinary way, that could be depended upon to remain gas tight, the attention of inventors and engineers was then directed to devising and perfecting suitable safety appliances ; first, to make the joints more secure, and second, to confine within certain limits any escaping gas and to conduct it through auxilliary pipes provided for that purpose to the surface of the earth, or above the surface, where it could be

disseminated in the open air without danger. Careful experiments were made, and the possible disturbances resulting from expansion and contraction, or from any cause, were duly regarded and provided against as far as human skill could suggest.

Such a system was perfected and applied to more than one hundred miles of pipes in Pittsburgh and Allegheny City with the most gratifying results. By its use in so thoroughly protecting the joints, we are informed that the actual loss of gas by leakage is less than one per cent. and the danger of explosions from this source is, therefore, practically overcome.

Explosions
and waste of
gas wholly
prevented.

This prevention of leakage presents a problem in which the public has a deep interest, and one which illuminating gas companies would do well to consider carefully. The average loss of illuminating gas by leakage from the mains has been ascertained and is admitted to be fully 12 per cent. This loss beyond doubt falls entirely upon the public, and what it amounts to in any given case is easily calculated.

If, in any case, with this leakage going on, the price to private consumers had to be, say, \$2.50 per thousand cubic feet, in order to yield the gas company a fair profit, the company, by perfecting its piping system and reducing the leakage to or below one per cent., which can readily be done, would realize the same net profit, with the price to consumers very much reduced.

How to re-
duce gas bills

Taking the official statistics of Philadelphia (see Appendix) as a basis of calculation, we find that the total output for 1885 was 2,757,844,000 cubic feet, of which the enormous quantity of 391,614,845 cubic feet was lost by leakage. This quantity, at \$2.00 per thousand cubic feet, the present price of gas in

Philadelphia, amounts to \$783,229.69, which very closely represents what would have been saved to the consumers in that city in 1885 had the piping system been perfected by the use of modern appliances so as to prevent, or nearly prevent, this leakage.

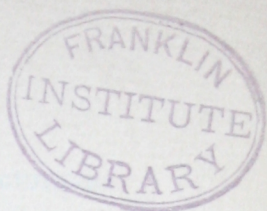
A menace to
health.

The public has a still further and a highly important interest in this saving. With 12 per cent. of gas constantly escaping and permeating the earth, it must soon become thoroughly impregnated, and the gas escaping again and continually through the pores of the earth to the surface, pollutes the air that we breathe and thereby imperils the public health. Again, in its permeation and passage through the earth it not only blights but kills any vegetation with which, for any length of time, it comes in contact, as witness square after square and street after street in many of our principal cities that have been entirely denuded of shade trees by the poisonous elements of escaping gas.

Detecting and Locating Possible Leaks.

System for
detecting and
locating leaks

This system of safety appliances comprises also the means of detecting and readily locating any leak that may possibly occur. This obviates the necessity of tearing up the streets, as is sometimes done in searching for leaks before they can be definitely located, and it provides an acceptable substitute for the old practice of illuminating gas companies, namely, that of "boring for leaks" at every joint, and perhaps then not finding any until the shade trees along the line begin to die and thus furnish the first definite evidence of location.



The Automatic Pressure Regulator.

With the pipe system and safety appliances perfected, the next step was to provide the necessary means to control and reduce the pressure of this gas so as to secure the best results at the point of consumption. Starting from the wells with a pressure of say two hundred and fifty pounds, the loss by friction will reduce this, under the usual conditions, to about fifty pounds at the city limits. Aside from the element of danger incident to such pressure, it must now be reduced to the minimum of two ounces per square inch and there held uniform, in order that the most economic combustion may occur.

An Automatic Pressure Regulator now became necessary, and it was soon forthcoming. This is indeed a very valuable addition to the inventions prompted by natural gas. It is capable of such delicate and complete adjustment that the pressure of the gas as it enters the regulator through the inlet pipe, may have a wide range of variation, which often occurs, and yet as it passes out of the regulator into the low pressure pipes it will be constant at two ounces per square inch or at any other degree required.

Gas pressure
positively
controlled.

With the pressure thus reduced and remaining uniform, it became possible to devise means for regulating the admission of air to the furnace, so as to obtain the proper admixture of gas and air to produce perfect combustion. The principle of perfect combustion in the use of this gas was thus so cleverly settled and the automatic device proved to be so accurate and reliable, that in tempering and annealing glass a marvelous result is uniformly produced, such as can scarcely be attained by the old methods. Likewise in generating steam and in the

manufacture of iron and steel the advantages thus secured are scarcely less important, while for domestic purposes this device lays the foundation of a safe system for utilizing the gas in any way that may be desired.

The Automatic Shut-off Valve.

Safety insured by automatic cut-off valves

This instrument is a complete provision against danger in the general and ordinary use of gas for domestic purposes, and it adds another to the list of important inventions directly referable to the problem presented by natural gas.

Accidents in houses prevented.

The service pipe which conveys the gas from the street main to the house can be readily made gas tight. The gas passes from the service pipe through the automatic shut-off valve into the house pipes. In the event of the gas supply being shut off in the street, as is occasionally necessary, this automatic shut-off valve will instantly close and it will remain closed until every stop-cock in the house has been turned off. This affords absolute protection against accidents that sometimes result from bad plumbing, and prevents gas that has been shut off and turned on again in the streets, from entering the house, which otherwise it might do while the occupants are absent, and be exploded by coming in contact with the flame of a lamp or an illuminating gas jet.

This device is so constructed that the admission, or automatic shut-off valve, cannot be opened except by the pressure of the gas in the house pipes, and then the gas has to pass through a hand-opened valve having so small an aperture that no accumulation of pressure is possible if there be a dangerous leak in the house pipes or if a single stop-cock is open.

The value of this device has been frequently illustrated by preventing what otherwise would have been disastrous accidents. It is practically an unfailing and absolute safeguard, and this fact has led to its extensive use for regulating the supply of gas to houses, and with most gratifying success. It is hardly necessary to say that such a safeguard inspires perfect confidence and adds much to the comfort of those using gas in their homes.

The Automatic Temperature Regulator.

The function of this device is to regulate automatically the temperature of a room. It is applied to the grate or stove burning fuel gas, and it gives results that cannot be obtained from any other form of fuel used in warming houses. It is readily adjusted for any temperature that may be desired, and it is so sensitive to the waves of heat and cold that the slightest change in the temperature of a room will instantly affect it, and it will, in turn, correspondingly open or close the valve through which the gas is supplied to the grate or stove, and in this way lessen or increase the heat. It thus maintains a perfectly even temperature in the room whatever changes may take place outside. In this way it effects a great economy in the use of gas.

Health and
comfort pro-
moted and
great econo-
my effected.

The great value of this invention will be recognized by all; it promotes health and comfort in the household, and in the sick-room it is an incalculable blessing. In this latter respect alone the inventor may well be proud of his achievement.

The Solution of the Problem Complete.

That the problem presented to the inventor and his coadjutors by the occurrence of natural gas has been completely solved, must now be apparent to all. The pipe systems and appliances for insuring safety and preventing waste in its conveyance and distribution, and the devices for its perfect adaptation to every use as fuel, have been brought to such a high state of perfection that there is really nothing further to be desired. This is fully attested by the experience in Pittsburgh and Allegheny City during the past two years, where the benefits realized and the advantages secured through the safe and economic utilization of this fuel are so great, that it is difficult to conceive of a parallel. The "two cities" in that short space of time have been transformed from the dirtiest to the most cleanly, and while this was occurring the same causes were working an economic revolution in the industrial arts scarcely less striking.

Great results
achieved by
Natural Gas.

The business
aspect.

The rapid growth and great financial importance which the natural gas business early assumed brought to its management in Pittsburgh a high order of executive and practical business ability, and to this may be largely attributed the uniform success which has become a part of its history. In referring to this aspect of gas utilization a writer in BRADSTREET'S, of Sept. 11, 1886, says :

"No more rapid growth has ever been known than that attending the opening of natural gas wells and the piping of this novel fuel to the iron, steel and glass works of Pittsburgh and its vicinity. The aggregation of capital has become very large and it has had the unusual good fortune to be safely and profitably employed from the beginning."

All cities must
use gas for
fuel.

The advantages that natural gas has conferred upon Pittsburgh cannot fail to impress their importance upon other cities

and lead eventually to the general adoption of gas — either natural or artificial — for fuel. For it is already an established fact which has the sanction and the earnest support of the most eminent, practical and scientific men everywhere, that gas is to be the fuel of the future. Natural gas has demonstrated that this must be so, and it presents an unanswerable argument in the superior qualities of its products of manufacture, and in its uniform economy and success.

Natural gas has the advantage of being a purer fuel and costing less than artificial gas, but the difference is not great and it would not be regarded as a factor in contrasting the difference of coal and gas for fuel in localities where natural gas does not exist. By comparison the great waste incident to the use of coal for fuel under the most favorable conditions plainly suggests that there is room for great economy in the substitution of artificial gas. It is a well known fact that in the ordinary use of coal for fuel there is a loss of from seventy-five to ninety per cent. of the heat units that might possibly be made available.

Great economy of fuel gas

In Pittsburgh natural gas is regarded as the harbinger of economic fuel and it is a well understood fact there that upon the exhaustion of the natural gas supply, if that should ever occur, an artificial gas will at once take its place. There is therefore no solicitude in the minds of investors as to the stability of the business or the security of investments in natural gas enterprises. A good substitute is close at hand and there is practically no limit to the extent of its production.

The Duty of Municipal Corporations.

Gas liable to
be found in
extended
areas.

As time goes on and the investigations as to the occurrence of natural gas and its probabilities and possibilities progress, the theory is constantly gaining ground that it may exist in rocks of any geological age, and that new horizons are liable to be found in formations that extend under vast areas in this country.

Enterprising
citizens will
drill test wells

It is admitted on all sides that its actual existence in commercial quantities in any locality that may be apparently favorable in a geological sense, can only be determined by drilling. In all such localities, therefore, it is safe to presume that enterprising citizens will test its possible existence by drilling wells. These tests, if successful, will bring a new duty upon municipal authorities in such localities, which should be properly regarded.

The great danger which we have shown to exist in the conveyance and distribution of gas under pressure has been made doubly manifest in the natural gas centers of Pennsylvania and West Virginia, by no less than seventy explosions, causing the loss of several lives and the destruction of a large amount of property.

It was perhaps not possible to achieve the great results in so short a time, that have been realized in Pittsburgh and vicinity, without making some mistakes and taking some hazardous risks. But the experimental period is passed and it would be next to criminal now, on the part of municipal authorities, to allow any but the most approved pipe systems and appliances to be laid in their streets and employed to convey and distribute this gas.

There is a weakness in human nature in this country to get on a little faster than is always safe, and there are men of enterprise to be found in many or most communities, whose sense of moral responsibility is not of the highest order and whose greed therefore might move them to employ unsafe systems if they should be unrestrained by legal authority. It is therefore necessary that the proper authorities carefully regard this duty and permit only such systems and devices to be employed as have stood the test of experience.

Municipal
Authorities
should be
vigilant.

In every city and town of a few thousand population in this country good men, men of the highest rectitude, serve for years as directors of illuminating gas companies. Generally every care is taken to administer the affairs of the company in accordance with the best business principles, and yet all of these men have quite overlooked an important engineering feature of their business, and thereby they have at least tacitly assented to a great menace to public health. Therefore we say the ill effects of twelve per cent. of the output of gas continually escaping from the mains into the earth to foully impregnate it and kill the shade trees, into cellars and sewers perchance to explode, and through the earth to the surface to vitiate the air we breathe, should certainly receive attention and the public authorities should promptly interfere and compel these gas companies to repair their lines, and if necessary adopt such modern appliances as are now known to exist and as will effectually prevent this great leakage and its attendant dangers.

Gas kills
shade trees.

It takes many years for a shade tree to grow and during this period it has to be carefully guarded against numerous enemies. Then again we have in many of our cities some proud old trees of the primeval forest that are centuries old. It is always regarded as a great misfortune to lose a shade

tree as though it were in some way closely related to the human family, and yet, whether only a few years or several centuries old, these trees are allowed to be killed at wholesale by gas companies, and this without even a mild protest.

Plain duties
of Municipal
Authorities.

In every city there is a Committee on Gas which forms an integral part of the municipal authority. This Committee should exercise a practical supervision over pipe systems, safety appliances, and the manner of pipe-laying, whether intended for the conveyance of natural gas, coal gas or water gas, for lighting or heating purposes.

In most cities there is a Board of Health. The functions of this board should be made to include the care of the public health against the insinuating poisons of gas as it permeates and escapes from the earth.

In some of the larger cities there is a Park Commission. When a tree dies they have it cut down and that is the end of it. This Commission should see to it that no tree comes to its death, or is blighted, by the effects of the poisonous elements contained in escaping gas.

These are some of the plain duties of municipal governments, and the people should not fail to insist that they be well and faithfully performed.

The era of fuel
gas upon us.

In glancing back over the benefits that natural gas has conferred upon humanity, we cannot fail to perceive that in forcing upon us the era of fuel gas, civilization has been advanced, and that, in prompting the efforts of the inventor and the men of science, dangers to life and property have been lessened, industrial prosperity has received a permanent aid and a great practical advantage, the burdens of labor have been lightened, and health, comfort and happiness have been made more secure. Surely these are blessings which merit our most sincere and grateful acknowledgements.

APPENDIX.

Analysis of Natural Gas.

MADE FOR THE COURT COMMISSION, MARCH 14, 1885,

BY GEORGE HAY, M. D. & C.

ANALYTICAL LABORATORY, 616 PENN AVE., PITTSBURGH, PA.

Composition of the Gas by Volume.

Carbonic acid	none.
Heavy hydro-carbons (Olefiant gas, etc.)	.50
Carbonic oxide	1.00
Oxygen	1.30
Light carburetted hydrogen (Marsh gas)	95.20
Hydrogen	2.00
Nitrogen	none.

First.—Gas taken direct from main contains no water. It is absolutely dry.

Second.—The gas allowed to stand over water for twenty-four hours, at temperature of 60° F., and measured at a pressure of 30 inches, mercurial barometer, contains in 100 cubic inches, .536 grains of water, which represents, therefore, its capacity for water at mean temperature and pressure.

Specific Gravity of the Gas.

Specific gravity of dry gas from main by effusion, as compared with air	.520
Specific gravity of gas saturated with water, as compared with air, by effusion	.554

Explosibility of the Gas.

Mixtures of this natural gas and air were made by volume, as below, and an electric spark passed through each mixture with the following results :

Natural gas volumes	1,	Air volumes	6—	No explosion.			
"	"	"	I,	"	7—	No explosion.	
"	"	"	I,	"	"	8—	No explosion.
"	"	"	I,	"	"	9—	Explodes.
"	"	"	I,	"	"	10—	Explodes.
"	"	"	I,	"	"	11—	Explodes.
"	"	"	I,	"	"	12—	Explodes.
"	"	"	I,	"	"	13—	Explodes.
"	"	"	I,	"	"	14—	Explodes.
"	"	"	I,	"	"	15—	No explosion.

The most violent explosions occurred with between ten and twelve of air to one of gas. The explosions were even less violent than with coal gas, volume for volume.

For comparison mixtures of coal gas and air were also made by volume, and the mixtures exploded as above with the following results :

Coal gas volumes, 1,	Air volumes, 5—	No explosion.
“ “ “ 1, “ “	6—	Explodes.
“ “ “ 1, “ “	7—	Explodes.
“ “ “ 1, “ “	8—	Explodes.
“ “ “ 1, “ “	9—	Explodes.
“ “ “ 1, “ “	10—	No explosion.

The most violent explosion occurred with seven volumes of air to one volume of coal gas, and the explosion was considerably more violent than with natural gas, volume for volume.

Illuminating Gas

consumed in Philadelphia, 1850 to 1885, with the totals and ratios to population, first of production, and next of private consumption.

PREPARED BY LORIN BLODGET.

	Population, U. S. Census.	Total Gas produced. cubic ft.	Ratio to population. cubic ft.	Private Lights, No.	Private Consumption, cubic ft.	Ratio to populat'n, cubic ft.
1850	408,762	182,016,000	445	115,004	131,258,400	321
1860	565,529	639,578,000	1,131	474,961	459,152,800	812
1870	674,022	1,241,485,000	1,842	871,562	898,359,680	1,333
1880	847,170	2,173,010,000	2,561	1,505,213	1,386,500,300	1,637
1883	950,000*	2,445,368,000†	2,574	1,651,230	1,685,934,000	1,774
1885	1,000,000*	2,757,844,000‡	2,758	1,796,494	1,911,296,300	1,911

*Estimated.

†413,676,600 is the use at works and loss by leakage=15 per cent., of which 12 per cent. is leakage. Loss by leakage in 1885 is 475,430,940 cubic feet, equal to 17 $\frac{2}{10}$ per cent., which includes nearly 3 per cent. used at the gas works, leaving a net loss from leakage for 1885 of 14 $\frac{8}{10}$ per cent. as before stated.

‡From the totals of gas produced for 26 years, the average of loss by leakage is calculated at 12 per cent., but this loss is given only with the consumption at works included, and together they average 15 per cent. as before stated.

The above figures are from official reports, except the population of 1883 and 1885, which is estimated.

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CCA





*A familiar
Scene.*



The New Era.



